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Polypyrrole based switchable filter system

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Abstract

BioTex is an EU funded project aiming to develop textile-based sensors for monitoring biological fluids. In the context of the project, there is a need to develop an effective sample delivery strategy for the wearable biomedical devices. A compact, electroactive switchable membrane would be useful as a valve to control the sample delivery within such devices. A method that employed inherently conducting polymers deposited onto a permeable substrate to form a switchable membrane was investigated [1, 2, 3]. By application of specific voltages, the permeability (pore size) of the membrane can be switched to swollen (expand) and contracted forms, which functions as electroactive plug or valve to manipulate the transport of liquid. It was anticipated that such switchable filter system would form the first stage in the development of a novel wearable platform in liquid handling, particularly for the transport of electro inactive species. It is expected that the use of a nano porous membrane promises advantages in improving the mechanical durability and performance in altering flow rate.

Disciplines

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Polypyrrole Based Switchable Filter System

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Introduction

BioTex is an EU funded project aiming to develop textile-based sensors for monitoring biological fluids. In the context of the project, there is a need to develop an effective sample delivery strategy for the wearable biomedical devices. A compact, electroactive switchable membrane would be useful as a valve to control the sample delivery within such devices. A method that employed inherently conducting polymers deposited onto a permeable substrate to form a switchable membrane was investigated [1, 2, 3]. By application of specific voltages, the permeability (pore size) of the membrane can be switched to swollen (expand) and contracted forms, which functions as electroactive plug or valve to manipulate the transport of liquid. It was anticipated that such switchable filter system would form the first stage in the development of a novel wearable platform in liquid handling, particularly for the transport of electro inactive species. It is expected that the use of a nano porous membrane promises advantages in improving the mechanical durability and performance in altering flow rate.

Experimental

Porous polyvinylidenefluoride (PVDF, nominal pore size 0.45 μm) membrane was sputter coated with a thin layer of platinum (10 nm) (see insert of Fig. 1). A small piece of platinised PVDF was then glued at the open bottom of plastic tube which contained the polymerisation solution (0.1 M pyrrole and NaDBS) and formed an effective liquid column exerting pressure to the membrane through which a liquid flux is maintained by gravity. This set up allowed the simultaneous polymerisation and flow rate monitoring for the optimisation of polymer thickness. While the height of the column held constant, the chronopotentiogram was recorded and the flow rate of electrolyte through the dynamic growing membrane was monitored. Finally three sample membranes with different film thicknesses (molar density of pyrrole units of polypyrrole) were selected for electrochemical controlled flow experiment that measured the change of flow rate by switching the pore size of the membrane electrochemically between +0.6V and -0.8V.

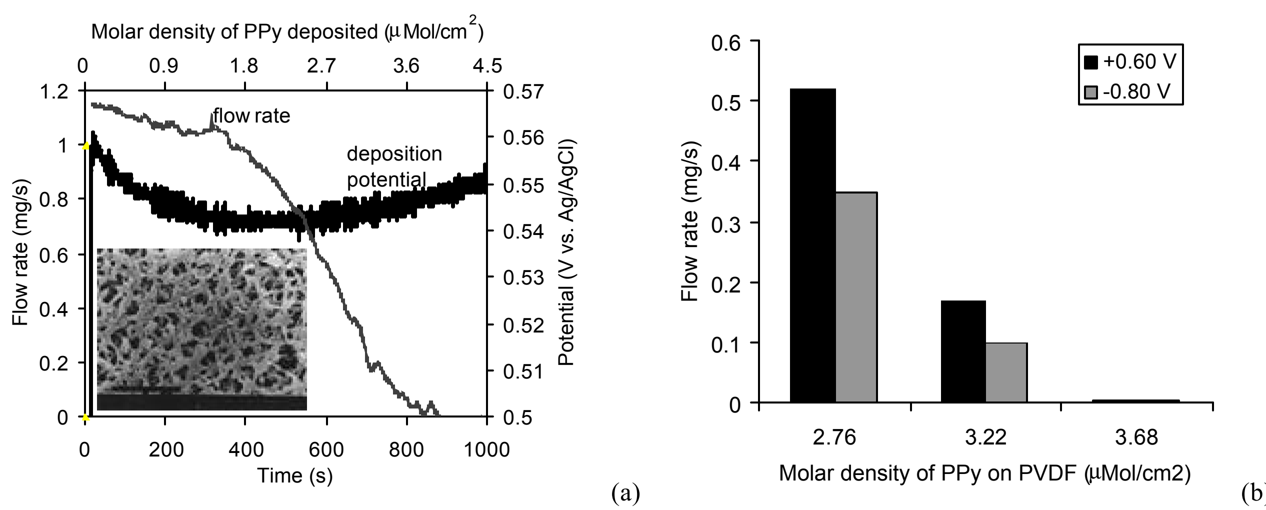

Fig. 1 (a). Simultaneously recorded chronopotentiogram and corresponding flow rate during the electrochemical deposition of polypyrrole on a platinised PVDF membrane, the insert shows the SEM image of platinised PVDF membrane, (b) flow rates for three samples of different molar density of PPy/PVDF filter membrane in response to the application of constant potential at +0.60 V and -0.80 V (vs. Ag-AgCl), respectively.

Results and discussion

The insert of Fig. 1 showed that the surface of platinised PVDF remained porous. The platinised PVDF has an average sheet resistance less than 1 ohm/cm. The low sheet resistance is important to obtain a relatively even coating of PPy by an electrochemical method. At a constant current of 1 mA/cm2, the deposition of PPy initiated a relatively higher potential of ~ 0.56 V and then gradually decrease to 0.54 V in ~500 s, afterwards increased again to 0.55 V (the broad-brush plot in Fig. 1.a). At the turning point at 500 s, a drastic decrease in flow rate occurs (light-thin plot in Fig. 1.a) showing that the pore size of the membrane had decreased significantly that liquid flow was hindered. After 600 s deposition time, the deposition potential increased which was believed to be due to the decrease of effective surface area of the membrane (Fig. 1).

Fig. 1.b showed the results obtained from opening/closing the pores electrochemically and the effect to the flow rate using the as-prepared PPy/PVDF filter membrane. In 0.1 M NaDBS, all the PPy/PVDF filter membrane produced a higher flow rate at 0.60 V (opened) than -0.80 V (closed). Upon the application of a constant potential of +0.60V, the flow rate increased as a result of the polymer contraction to open up the pores. At -0.80 V, PPy/DBS increased its volume by taking up solvated cations at a reduction potential [4]. For the sample PPy at a molar density of 2.76 μMol/cm2, the largest decrease of the flow rate was observed from 0.52 mg/s at +0.60 V to 0.35 mg/s at -0.80 V.

The flow rate of liquid through PPy/PVDF depends on the density of its open porous structure, the nature of incorporated free liquid in the polymer network and the surface properties of polymer membrane. At a constant cross-membrane pressure, an electrochemical stimulation (i.e potential) has several effects in altering the flow rate: (1) changes polymer bulky volume resulting in the change of average diameter of open pores across the filter membrane (2) changes the content of incorporated solvent liquid, (3) changes the surface energy of the polymer. In this study, the volume change in the pore size dominates the change in flow rate.

Conclusion

A polypyrrole based switchable filter system was successfully constructed and the switching properties in altering liquid flow rate were characterized. It has the ability to alter the transport of liquid in response to an applied potential. Such a switchable filter system will have important implications in the development of advanced liquid handling devices.

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